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A MEMOIR ON THE WATER SUPPLY
OF THE CITY OF SAN FRANCISCO

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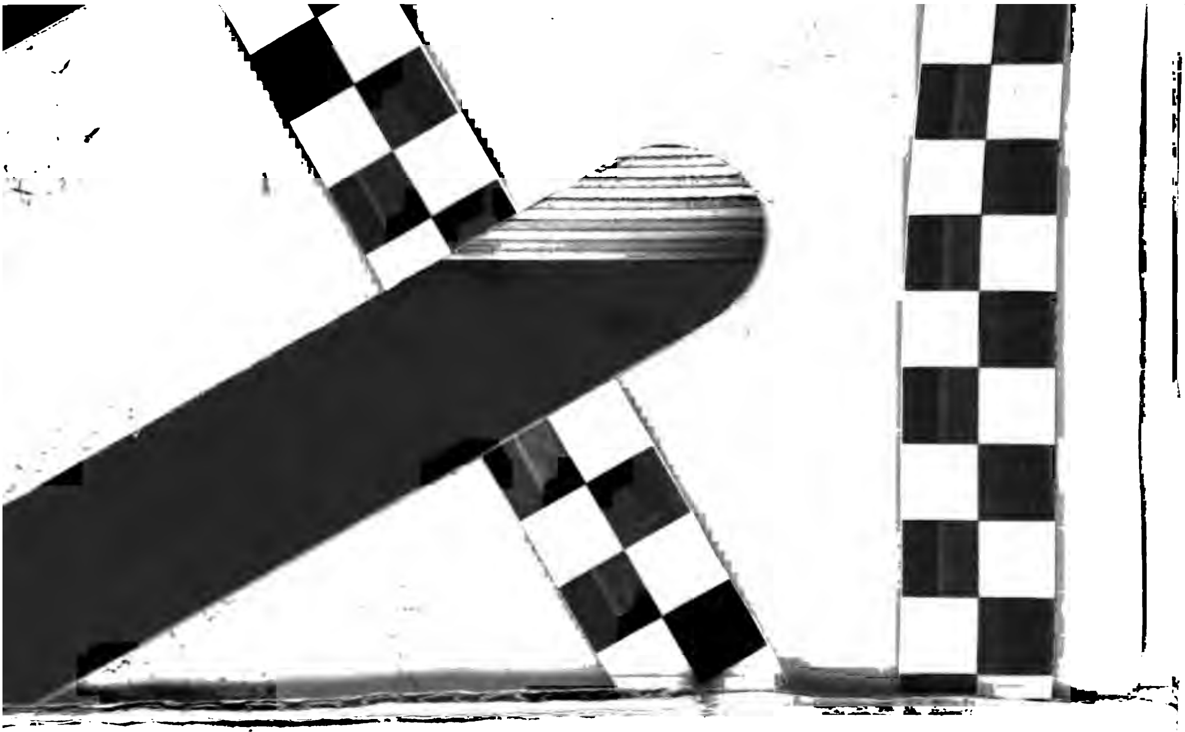

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A MEMOIR

ON THE

WATER SUPPLY

OF THE

CITY OF SAN FRANCISCO

BY

WM. J. McALPINE.

1879:
C. A. Murdock & Co., Printers, 532 Clay St.

WHO IS WM. J. McALPINE?

The following quotation is from the Evening Bulletin of July 15th, 1878:

"The name of William J. McAlpine, of New York, is associated with some of the greatest engineering works on the eastern side of the continent. He was at one time Chief Engineer of the Erie Railway. He was also the engineer who constructed the Albany, N. Y. and Chicago Water Works. The reconstruction of the Erie Canal was also accomplished by him. He is regarded as one of the most eminent engineers now living."

It might also have said that he is one of the four oldest members of the American Society of Civil Engineers, and was its President for many years; was for several years the only American member of the Institution of Civil Engineers of Great Britain, which is composed only of the most eminent Engineers of Europe; has been for many years, and is at present, a member of the Institution of Civil Engineers of France, Austria, and other European Societies; is a member of the American and Franklin Institutes, and of almost all of the scientific societies of the United States, etc; has been Engineer in Chief of the United States Navy, and constructed the U. S. stone graving dock at Brooklyn, N. Y. one of the most difficult engineering constructions in the United States; has been State Engineer and Surveyor-General of the State of New York, and was engaged on the New York State Canals in constructing the large impounding reservoirs for the Chenango Canal, and also the most important works on the enlargement of the Erie Canal, immense aqueducts, locks, etc; was the Assistant President and Chief Engineer on the Erie Railway, the Galena and Chicago (now the Chicago and Northwestern), and also on the Ohio and Mississippi Railway; was the Chief Engineer, and designed all of the plans for the Brooklyn Water Works, and designed and executed the Water Works of Albany, N. Y., Chicago, New Bedford, Mass., and of many other cities, and has been Consulting Engineer on some of the largest bridges, railways, water and other hydraulic works in the United States and foreign countries; was the Engineer, and at one time, the General Superintendent of the New York State Capitol, at Albany; was the Chief Engineer employed by the Iron Gate (Eisen Thor) Commissioners, for rendering the cataracts of the Danube navigable for fifty miles on the borders of Wallachina, Servia and Turkey; is the author of Modern Engineering, Railway Management, The Principles and Practice of Public Water Supply, Engineering Tracts for the People, and of many other treatises on Engineering subjects.

A MEMOIR

On the subject of Supplying the City of San Francisco with Water;

BY

WM. J. McALPINE.

A public water supply to a city should have sources adequate, not only for the present demands for domestic uses, for manufactories, for public baths, for the shipping, fountains and irrigation of private and public grounds, for sprinkling the streets and flushing the sewers, and for the quick extinguishment of fires, but also for all of these purposes when the population shall have been trebled, and in addition thereto, with the means of extending the works at a future time, in conformity with some general plan, which, while adapted to a supply for the present, will permit of the future extension above indicated, with the least loss of the first expenditure.

The sources of water available for the city of San Francisco are as follows:

1. From wells within the area of the city or contiguous thereto.
2. By collecting the rainfall upon the elevated lands of the Peninsula south of the city, in large storing reservoirs, and conveying it in conduits to distributing reservoirs within the city, from which it may be distributed to all parts thereof.
3. By a corresponding collection, impounding, conveying and distributing the rain, which falls in the Mount Diablo coast range of mountains nearest the city, as in the Calaveras District.
4. Also from similar districts on the Coast range and from streams or lakes immediately beyond them.
5. From lakes and streams on the mountain slopes of the Sierra Nevada and the conveyance and distribution to the city as before mentioned, and

6. From modifications and combinations of the foregoing plans.

Schemes for a supply of water from these several sources, have been more or less examined and discussed by civil engineers and others, whose printed reports furnish a part of the data necessary to determine the relative advantages and expense of each. I have personally examined the sources, sites and routes of these schemes, and have considered all of the other matters necessary to a general, and in most cases a sufficiently particular understanding of the whole subject of the present inquiry.

The result of these studies will now be presented under the following general heads:

FIRST. The QUANTITY of water which is *now required* for the City, and the *additional amount* which will probably be demanded from time to time.

SECOND. The QUANTITY which can be *obtained* from each of the reliable and reasonably practicable sources.

THIRD. The relative QUALITY of the water which each source will furnish.

FOURTH. The CHARACTER, EXTENT and comparative EXPENSE of the several plans for procuring the requisite quantity of suitable water, for the present and future demand, from each source.

FIFTH. A COMPARISON of the most feasible of the schemes in regard to the usefulness, certainty of construction and maintenance, quantity and quality of the water and of the expense of introducing the same.

FIRST.

The quantity which is now and will probably hereafter be required.

The quantity of water which is required for all of the purposes for which a public work is intended to supply, as hereinbefore enumerated, may be considered as equal to thirty gallons a day, applied to the whole number of the population. This amount of water may be divided into three nearly equal parts, viz.: *One third* for the domestic consumption (for potation, cooking and washing for the whole population, and for baths and water closets, etc., for a portion of the people); *another third* for the various mechanical operations, hotels, restaurants, stables, public baths, fountains, etc, and for shipping; *another third* for the sprinkling of streets, flushing of sewers, extinguishment of fires, and for wastages.

When planning works, which are to be under municipal control, which may at times, be less efficient than individual management, the conservative engineer considers it necessary to have at command, twice the above named quantity. The experience of the best managed public water works of the Eastern cities confirms this estimate. The rate of consumption in the European cities is much less. The difference is due to the habits of the masses of the people of the two countries. The present population of three hundred thousand, in San Francisco, would by this rule, consume an average of nine millions of gallons daily, as a minimum and a possible maximum of twice that quantity.

Any source of supply, to be entitled to consideration as a whole, should be sufficient to readily furnish thirty-six million gallons daily and ultimately a hundred or more millions to meet any probable and possible increase of the population, business and other demands for water.

A source which cannot furnish these quantities can only be considered as an adjunct to some other scheme.

SECOND.

The quantity which can be obtained from each of the proposed sources.

Preliminary to the consideration of this question, it may be proper to recall to recollection, that the source of all fresh water is primarily from the ocean, and secondarily from the atmosphere.

The quantity of fresh water which can be obtained from any district of country, depends upon the amount of the precipitation, the area steepness and porosity of the water-shed, the losses from evaporation, etc.

The capacity of the atmosphere for the absorption of moisture depends upon its temperature.[*] A warm wind blowing over the ocean becomes charged with watery vapor; When it reaches land which is cooler, it discharges some of it in dew, mist or rain. The ocean winds which are driven up the mountain slopes, encounter more and more cooled earths, and discharge more and more water in proportion to the elevation to which they are driven.

The precipitation at San Francisco averages two feet in a year; the chief part of the rain falls within four months, and a large proportion of it generally falls during two of these months. The rainfall on the top of the surrounding hills, is about twice as much as on the low parts of the City. While at the top of the Sierra it is from eight to ten feet, or more.

The temperature of the ocean winds, and of the lands along the coast, is nearly the same during the seven summer months, and the consequence is that no rain can fall, but during the five months of the autumn and winter there are greater or less differences between the temperatures of the ocean winds and of the land, which produce copious winter rains. The precipitation being always in proportion to these differences in temperature.

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[*] NOTE—A cubic yard of air at a temperature of 32 degrees, Fahrenheit, is capable of containing seven grains of water, and at 50 deg. about fifty grains; from 50 to 80 deg. a cubic yard of air will contain about as many grains of water, as the number of degrees of the thermometer. Above the temperature of 80 degrees, the capacity to receive watery vapor increases rapidly, and at 212 degrees the air can receive its own bulk. The tension of the water being then equal to that of air and ebullition is produced.

The rain water which is thus precipitated upon the land, divides itself into three portions; one of which passes off *visibly*, over the surface to its parent source the ocean; a second part enters the porous earth and rocks and flows *invisibly*, either directly to the ocean or to the flowing springs, or superficial water courses, and the remainder of the rain is *evaporated* from the surface of the ground, water courses, etc.

Generally from half to two thirds of the rainfall passes off either superficially or subterraneously. The former flows off comparatively quick depending upon the steepness of the surfaces of the ground, and the latter much more slowly, depending upon the looseness or compactness of the soil or rock.

The apparent mystery of the supply of water to Artesian wells may be easily explained. Strictly speaking, the term artesian should only be applied to water which flows above the surface of the ground.

Sometimes in a valley surrounded by higher lands there is found a porous stratum of earth or rock between impervious layers above and below it, all of which extend to and crop out on higher ground, and also extend beneath the soil of the valley. Under such conditions, the rain which falls upon the exposed surfaces of the porous stratum, sinks into it, and if this channel of water is pierced, by boring in the valley, the water will ascend in a tube, to the level of the outcrop on the surrounding hills, though sometimes the water in the porous stratum, has some other outlet at a level lower than the hill tops. The height to which such water will rise in the boring tube and in a vertical pipe placed on top of it, is the measure of the elevation of the land from which the "flowing well" receives its supply, or, in the exception before stated, it measures the level at which this water has another escape.

Common wells in which the water does not overflow, sometimes receive their supply in the same manner, but more generally they merely drain the water from the interstices of the surrounding soil.

The quantity of water which can be permanently obtained from an artesian well, is exactly measured by the area of the porous stratum which is exposed to the rainfall. The elevation to which such waters will flow, and the quantity which the well will ultimately discharge generally determines the source of its supply.

The quantity which can be permanently obtained from any common well, depends upon the cubical amount and porosity of the soil which it drains. If two or more artesian wells are sunk near a first one, in a homogenous soil and the overflow from the latter is reduced in height, or the quantity is materially lessened, it shows that the source of supply to all is not only the same, but that it is of very limited extent and probably near at hand.

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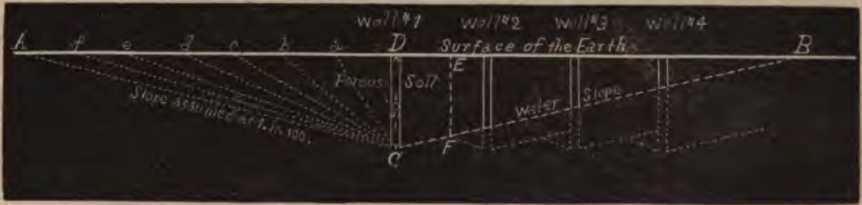
The same may be said of common wells, whenever several contiguous ones have been sunk into a homogeneous soil, and a considerable quantity of water is attempted to be pumped from each well. The quantity which the first well was capable of furnishing will be successively reduced by that which is pumped from those which were afterwards dug. If we take a case similar to that which presents itself in many places in this City, where a common well has been sunk, say fifty feet deep in porous soil, through which the quantity of water pumped, will flow to a well, on a slope of one in one hundred, this well will drain an area of nearly two miles in diameter at the top, and in the form of an inverted cone of fifty feet deep.

If another well is afterwards sunk to the same depth, within the same area, the quantity of water which could have been obtained from the first well will be considerably reduced; and if several such wells are sunk within the same area, the aggregate supply attainable from all of them, will be but little more than that which was originally obtained from the first well.



On the above diagram well No. 1 was the first one sunk into a body of homogeneous soil like sandy loam.

The rainfall of previous years will have charged the soil with all of the water which it can contain, which may be assumed at one fifth. When a given quantity is being pumped from this well, the water will continue to flow to it, until the slope of the surface of the flowing water becomes say one in a hundred: that is, that the head necessary to overcome the friction caused by the earth particles, is equal to one foot in one hundred feet. The cubical contents of the inverted cone of earth of ten thousand feet diameter and fifty feet deep at the apex, is nearly four thousand millions of cubic feet of earth, which will contain eight hundred millions of cubic feet of water, or six thousand millions of gallons. If pumps be applied to this well during the two hundred and fifty days, when no rain falls, it will furnish an average daily quantity of twenty-four millions of gallons, but only for one season. After which, if no rain should fall, no more water could be obtained from the assumed drainage content of that well.

In San Francisco the rainfall averages two feet deep, falling in the remaining one hundred and fifteen days of the year, and if the whole of this rainfall on the surface of the ten thousand feet diameter, could be collected in its soil and none of it ran to waste, or was lost by evaporation, the subterranean reservoir of water would amount to nearly twelve hundred million gallons. In practice, however, it is found that not more than one third of the rainfall can be made available, say four hundred millions of gallons, and therefore the well in question, would thereafter, only furnish an average of a little more than a million of gallons a day for the year.

The catchment area of the water-shed above assumed, measures $2.\frac{81}{100}$ square miles, which gives an average of 383,000 gallons a day for each square mile. But the rainfall on the higher parts of the city is greater than two feet, and if it averages three feet, the above supply would be 574,500 gallons a day, from a square mile.

Returning to the diagram and the above remarks, we find that although the well in question, would give eight millions of gallons a day for two hundred and fifty days, it would never after the first eight months, give more than an average of 574,500 gallons a day for the succeeding years.

The rainfall at San Francisco was only $7.\frac{4}{10}$ inches in 1851, $10.\frac{08}{100}$ inches in 1864, $14.\frac{10}{100}$ inches in 1871; from which we may infer that there would frequently occur years, when this well would not supply an average of 300,000 gallons a day..

When well No. 2 on the diagram was sunk, say at a thousand feet from No. 1, it would cut off nearly a third of the quantity which No. 1 could originally furnish, and if a circle of wells should be sunk around No. 1 within a thousand feet distance from it, well No. 1 would not furnish an average of 20,000 gallons a day.

The lines Ca, Cb. etc., represent the slopes of the water which will successively flow to well No. 1, until it has exhausted all of the fluid which had accumulated, during many previous years, within the body of earth embraced in the area of A B diameter, by D C, the depth of the inverted cone.

The lines B, E, F, represent the area (in a vertical section) which well No. 2 will cut off from the original supply to well No. 1. The area of the cut-off on the surface of the ground by well No. 2 will be nearly one third of the whole of the original area which had previously supplied No. 1.

If we take the whole of the City to the north and east of the surrounding hills, as equal to about twelve square miles, we shall find considerable areas of rocks which are bare, and others lying beneath a soil which is compact and nearly impervious to water. These rocks and impervious earths form natural barriers to oppose any inflow of fresh water from any district beyond these hills.

The surface earth and the excavations and borings throughout the City, show that the soil which overlies the rocks, is generally porous sand or gravel, and in some places interspersed with strata of clay or mud.

The rocks which form the Diablo ranges, fifty miles to the eastward, have no porous strata between water-tight ones, and hence no artesian supply of water can come from that, or any other source eastward of this range. The dip of these rocks is so nearly vertical, that even if they held and conveyed water, borings in San Francisco would have to be made many miles deep, to reach such supposed sources of water. A supply of artesian water from the Sierra Nevada slopes is entirely cut off by the impervious barriers of the Diablo range, and no water derived from that source, could be reached by any borings made in the City.

The city itself is surrounded by impervious rock barriers on two sides, and by the salt water of the Bay on the other sides; *an artesian supply is therefore impossible from any source beyond itself.*

All of the so called, artesian wells in the City, and all others which may hereafter be bored, must, necessarily, now and forever, derive all of their water from the rain which falls upon only a portion of the before mentioned twelve square miles.

The rainfall upon this district, does not exceed an average of three feet depth a year, and in some years is less than half as much. That portion of the rain which falls upon the bare rocks, or those which are scantily covered with earth, flows off quickly to the Bay, and but little of it enters the pourous soil beneath the city. That portion which falls upon the roofs of the houses and the water-tight sidewalks and pavements, runs off rapidly in the gutters, or through the sewers to the Bay. The remainder may, for the present, be considered as having entered the porous soil through which it will slowly flow to the surrounding salt water.*

If a systematic arrangement of wells throughout the City, should be resorted to, the aggregate quantity which could be obtained therefrom can be determined with approximate exactness. There are considerable areas contiguous to the Bay and its re-entering valleys where the rainfall would run off quickly to the Bay, and would not find its way to the porous soil for the well supplies.

The roofs of the houses and the water-tight sidewalks and pavements convey the rain which falls upon them to the gutters and sewers, and would also be lost to the well supplies. And there are localities, such

*Note. All of the rain water which enters the porous earth each year, ultimately reaches the sea and generally within the current year, during which it falls.

The surface of this water contained within the earth, will be found at its maximum elevation and slope, at the end of the rainy season, and at its minimum height and grade at the end of the season of no rain.

When the annual rainfall is greater than the average of a series of years, the surface of the subterranean water, flowing to the sea, will be found on a steeper slope, and when it is less than the average, the slope will be flatter.

The discharge of this subterranean water into the sea, commences as soon as the first rains have saturated the earth nearest to the sea water, and will continue until the whole of the season's rain, which has soaked into the soil, has reached the sea.

All of the rain water which may have filled the porous earth nearest to the Bay, during the rainy season, will have flowed off early in the dry season; and then the water from those portions which are next nearest to the Bay will flow off to it a little later, and so successively until a considerable portion of the water in the porous soil over the whole water-shed will have flowed off and be lost to the daily supply for the latter end of the dry season, to the wells which it has been assumed will be dug.

as near the cemeteries, certain manufactories and populations, where wells for a domestic supply of water would be inadmissable.

For the present purpose it is sufficient to say that all of the wells which could be sunk in the city would not furnish an aggregate permanent supply, for all time, of six millions of gallons a day, of water suitable for domestic purposes.

This assertion may be met by a reference to some wells in the city which now furnish a large quantity of water, and that if other wells should be sunk in favorable localities, the aggregate supply therefrom would exceed the quantity which has been above estimated.

The reply is, that the porous soil beneath the City has been charged to repletion, with the rainfall of a great many previous years, and if an amount of water should at any time, be drawn therefrom, greater than that which the rains will now furnish, the original stock of stored water would eventually be exhausted ; after which the supply obtainable from the wells, would be exactly measured by the proportion of the future rain water which will flow to them.

It is said that no water is lost ; even that which in its liquid form and in the juices of meat, vegetables, etc., is consumed by man and animals in a city, is more or less restored to the porous soil from which the wells must derive their supply, and by that quantity of restored water, it will be acknowledged that the above estimates of quantity are too small.

The natural repugnance of all persons to the use of such foul restored water, even when mixed in comparatively small portions with better water, will, as soon as realized, lead to measures which will convey a considerable portion of such sewage water to waste in the Bay, and ultimately, by these measures, while the City wells may be rendered less baneful, the supply therefrom will be greatly reduced. There will, however, always be enough sewage and objectionable matter admitted to such wells as to render them undesirable.

There are some mechanical and other purposes for which such waters as can be procured from wells in the city, can be used, but as soon as their true quality is generally understood they will never be used for domestic purposes.

SECOND.

An ample *quantity* of water for the present and future demands of the City, can be obtained from each of the sources named on page 1, except from wells within or near it.

In a report of the Chief Engineer of the Spring Valley Water Company, I find that during a period of seven years, there was collected for use in the Peninsula reservoirs of that Company, six and a seventh millions of gallons of water from each inch of rainfall on each square mile of the water-sheds of those reservoirs.

The mean rainfall during these seven years was $23.\frac{71}{100}$ inches at San Francisco, with a range between $15.\frac{21}{100}$ inches and $28.\frac{23}{100}$ inches ; and one year (1872) of $38.\frac{32}{100}$ inches. At San Andreas, elevated 455 feet above tide, the mean was $44.\frac{75}{100}$ inches, with a range between $30.\frac{52}{100}$ inches and $47.\frac{63}{100}$ inches, and one year (1872,) of $82.\frac{57}{100}$ inches. At the Pillarcitos, elevated 696 feet, the mean was $47.\frac{70}{100}$ inches, and a range between $38.\frac{88}{100}$ inches and $50.\frac{31}{100}$ inches, and one year (1872) of $78.\frac{28}{100}$ inches.

The water-sheds of the elevated portions of the Peninsula nearest the City, are probably six or seven hundred feet above tide, and the rainfall thereon, probably averages about four feet a year, and if it was all stored so as to bridge over the years of rainfall, which are below the mean, each square mile of the water-shed, would furnish an average of 800,000 gallons a day.

The minimum supply now required by the city, as stated on page 4, is nine million gallons daily, which would require a water-shed of 11¼ square miles. The maximum present demand would require 22½ square miles, and in a few years, the growth of the city will require the water from 45 square miles, and ultimately from 100 to 200 square miles of water-shed.

The present works of the Spring Valley Water Company, on the Peninsula, have 27½ square miles of water-shed, and with the aid of a new reservoir, which can be built when necessary, it will have the supply from 39 square miles.

The Company has also surveyed other accessible water-sheds on the Peninsula, which will increase the whole catchment, under their Peninsula system, to more than one hundred square miles.

I have personally examined the eastern slope of the Peninsula range, as far south as the proposed site of the reservoir on the north branch of the San Francisquito creek, ten miles south of the San Mateo, and find that with a dam of about a hundred feet height, a storing reservoir, capable of containing about three thousand million gallons of available water, can be obtained. The water from this reservoir can be conveyed to the proposed Cañada Raymundo reservoir, by a canal, conduit and pipes of ten miles length, including a tunnel of about a mile in length.

The area of the water-shed which this scheme will utilize, is about twenty square miles, and in conjunction with the other very large contiguous storage capacity of the Spring Valley Works, this district will furnish a large additional supply.

The problem of the storage capacity which must be provided on this part of the Pacific Coast, must be considered differently from what it would be on the Atlantic.

On the latter, the rainfall, on the average, is distributed with tolerable regularity over each month of the year, and the extremes of the annual precipitation are not so great as on the Pacific, while on the Pacific Coast all of the rains occur during four or five months, and there is no precipitation during the remainder of the year. The total annual quantity is much less, and the extremes between the years is much greater than on the Atlantic.

For these reasons, the provision for the storage of the rainfall here must be much greater, to bridge over the long period of no rain, and this must again be increased, to provide for a supply during a succession of several years of small rainfall.

The aggregate storage capacity of the reservoirs, which are now built by this company, is more than twelve thousand million gallons, and this will soon be increased by thirty-four thousand million gallons, making a total storage, comparatively near the City, of forty-six thousand million gallons.

This immense storage is more than sufficient to meet all the requirements of the case, but the plans of theCompany, contemplate the utilization of the whole storage in a manner which will presently be mentioned.

The next nearest source of supply is from the Calaveras District, on the western slopes of the Diablo Coast Range of mountains.

I have visited the site of the proposed reservoir on the Calaveras Creek, and the route of the tunnel and conduit by which the water from the district is proposed to be conveyed to the city. I have also examined the reports of Messrs. Schussler, Scowden and Mendell on this subject.

The reports show that, with a dam 183 feet in height, a reservoir with a capacity of thirty thousand million gallons would be formed. That an area of water-shed of a hundred square miles would be obtained, where the mean annual rainfall at the reservoir, is 28 inches per annum, and probably much larger on the high mountain slopes of the water-shed.

Mr. Schussler compares the character of the water-shed and the evaporation from this reservoir with those which have been tested on the Peninsula, and estimates that five and eight-tenth million gallons for each inch of rainfall, would be derived from each square mile of the water-shed of the Calaveras. This estimate gives more than sixteen thousand million gallons a year, or an average of forty-four and a half million gallons a day.

Col. Mendell, however, from some rain gauges established by him for three months, in 1877, concludes that the rainfall on the higher portions of this water-shed is not greater than at the reservoir, and says that "the product of the Calaveras water-shed cannot prudently be estimated to amount to more than thirty millions of gallons daily. * * * * * If additional storage can be provided, the daily average supply will be increased proportionately."

He bases his estimate upon a reservoir with a capacity of storage of twenty-five thousand million gallons. Mr. Schussler proposes a reservoir one-fifth larger, which would increase Col. Mendell's estimate to thirty-six thousand millions daily.

Messrs. Schussler and Scowden have proposed to increase the supply from this source when needed, by introducing into the Calaveras reservoir, the water of the Arroya Honda and Arroya Valle, creeks immediately contiguous thereto, which, together, have one hundred and forty square miles of water-shed. With the same depth of water-fall and ratio of collection as used for the Calaveras Creek, it would furnish an additional supply of over sixty millions of gallons a day, and a total of more than a hundred million gallons daily from the whole of the Calaveras District. There are many places on these streams, which offer facilities for the construction of as large storing reservoirs as may be necessary to impound and preserve the flood waters and those of the years of plentiful rainfall. Therefore, we may conclude, that the Calaveras District is capable of affording an ample supply of water to meet the utmost demands for the City, however extensive that demand may be in the future.

I have not been able, except in a general way, to personally examine the other sources of supply, viz: from the lakes and streams on the Sierra Nevada slopes, from Clear Lake, etc., and from the San Joaquin River, but the reports of the engineers already named, demonstrate that each of them will furnish the necessary *quantity* for the present and future demands of the city.

I am therefore warranted in stating that each one of the sources of supply mentioned on page —, except that from common and deep wells in the city, may be made competent to furnish the desired quantity of water to San Francisco.

THIRD.

The THIRD general question proposed to be considered, is to determine the relative QUALITY of the water which can be procured from each of the sources before named.

It may be repeated, that all fresh water is derived primarily from the ocean, by the operation of natural distillation.

For such practical purposes as the present enquiry, the water which is precipitated from the atmosphere may be considered pure.

Water readily seizes hold of, or enters into combination with almost every substance with which it is brought in contact, and what is important in the present examination, is that it eagerly absorbs, and reluctantly parts with, those substances which render it most objectionable for domestic uses.

The impure gases from combustion, and those which arise from the vast masses of refuse, decaying vegetable and animal bodies which abound in the fouler parts of a large city, all float in the atmosphere over large populations, and are all seized upon by the falling rain water, and materially injure the quality of what would in the country, be very pure water.

When the fluid reaches the surface of the earth, it is brought into contact with the decaying vegetable and animal products, which it rapidly dissolves and incorporates, and when the rain water passes into the interstices of the earth, or porous rocks, its great solving power enables it to decompose and incorporate the earthy and mineral matter with which it comes in contact.

From these general statements we may obtain the relative degree of purity of the water which can be obtained from each of the several sources, without resort to chemical analysis.

The water which is obtained from wells within the City, must necessarily contain all of the contaminations which have been enumerated, viz: from the impure gases always existing in the atmosphere over the city; from absorption of the effete animal and vegetable matter, which is so abundant on the vacant lots and grounds around the dwellings of certain classes of the population; from the earthy and mineral salts in the soil; and from the leakage of stables, privies, imperfect house-drains and sewers—the most hurtful and repugnant of all contaminations.

Water which is brought into contact with excrementary matter from the human body, imbibes therefrom the most deadly and disgusting of all the pollutions to which it can be subjected.

The Arab, Turk, East Indian and the Chinese, only half civilized, hurry such matter from sight, and deposit it where its emanating gases and germs will perform the natural functions of dissolution, without coming into contact with any of the air or water which man is compelled to breathe or use.

It is only among the civilized Caucassians, and in their densely populated cities, that these obviously necessary sanitary measures are disregarded, and men, women and children are forced to drink the deadly and disgusting water obtained from wells within a city.

Many of the open privies, earth closets, water closets and leaky house drains and sewers, discharge their contents into the adjacent soils, and the water from the next rain percolating through this filthy soil, becomes contaminated with it and flows on to the nearest well.

If a deep well is sunk through the upper porous soil and one or more layers of clay, the smooth exterior surface of the iron pipes offers a ready conduit to the contaminated water, which will then enter the pipe at the bottom of the deepest well and poison the whole supply therefrom.

I have been informed, and have observed that a great many of the sewers of the City have been very badly constructed, of loose, porous brick masonry of inadequate thickness, laid up with common mortar of very bad quality, and that these sewers leak into the adjacent soil, a considerable amount of their contents. So far as this leakage occurs, it is a terrible source of corruption to any contiguous wells of water.

The enteric fevers and zymotic diseases, which prevail to so frightful an extent in many of our American cities, have been traced directly to the use of water from wells, which have been poluted by the admixture of sewage matter and drainage therefrom.

The chemical analysis of the waters from many of the old, long used wells in European cities, and from those formerly in use in some of the American cities, (some of which yet continue) show how foul and corrupt all such sources must be, under the similar conditions which, we have endeavored to demonstrate, must exist in almost every well, shallow or deep, to which now or hereafter a resort is had for any portion of the supply for domestic uses. *

Samples of the water from some of the so called Artesian wells, from which more or less of the supply is obtained at the larger hotels, and at other places are herewith submitted and also of the same waters, to which some simple reactions have been applied, (which any gentleman may repeat) which show some of the ingredients which are always to be found mixed with all of the waters from such sources. These simple experiments confirm what has been before stated, viz: That even these deep wells, which are supposed to be the most pure which can be found, are utterly unfit for domestic uses.

Experienced analytical chemists will determine the exact quantity of each of these deadly or unwholesome ingredients in these well waters, but even their best efforts, though generally successful, do sometimes fail to detect those more minute germs which convey the most deadly diseases to people who are compelled to use it.

It is refreshing to turn from these disgusting considerations of the foul water, which all city wells must necessarily furnish, to those comparatively pure ones, some of which are within easy reach, and others more remote from your City.

The geology of the Peninsula and that of the Diablo Coast Range of mountains shows that their rocks are chiefly of sandstone and slate, often metamorphosed by igneous action; and some veins of the same rocks, and also of limestone and granite, which have not been changed. Wherever the earth overlies these rocks, or is found in the contiguous valleys, it has been formed from their disintegration.

The character of the water which falls upon the bare rocks or their earth covering, or of that which flows over or through the soil of the hill slopes and valleys, will be determined by ascertaining the character of the soluble constituents of these rocks and earths, and of the extent of the decaying vegetable and animal matter upon or within them.

The steep slopes of the water-shed will prevent the pure falling rain water from contact with the rocks, and especially the metamorphosed ones, long enough to dissolve and absorb much mineral matter from them, and in fact almost nothing that will make it unwholesome It may be rendered a little harder, but not at all injurious for potations.

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*Note.—By a new process the London chemists have analyzed some of the well water in that city, and determined the "germs of sewage" by the quantity of albumenoid ammonia.

These wells contained from one quarter to three parts of these "possible sewage germs" in one million parts of the well waters.

These germs cannot be removed by filtering, as they are smaller than even blood globules, and their vitality is not destroyed by boiling the water.

The water-sheds above referred to are covered with a scanty growth of grass, bushes, and in the ravines, of trees. The grasses and foliage of such districts decay during the midsummer, and the gases of decomposition will have been driven off before the autumnal rains commence, hence the falling rain water has but little, if any, decayed vegetable matter to come in contact with, and must flow off with almost no vegetable contamination.

Animal life even of minute and ephemeral character, cannot exist to any considerable extent, when thus deprived of vegetable food, and it is therefore to be found only in small quantity upon these water-sheds, and by its necessary death and gaseous exhalation in midsummer, cannot possibly, sensibly affect the waters which subsequently flow off from these sheds.

We then have a source of water which is comparatively free from the contaminations of the mineral and earthy salts, and from vegetable and animal effete matter, and it must therefore be pure and of the best quality for domestic purposes, indeed its quality is and must necessarily remain superior to that which is supplied to any other City within my range of observation.

This characteristic of the quality of water applies equally to that which may be derived from the elevated portions of the Peninsula, of the Coast range, and as far as two hasty trips have enabled me to judge, to the slopes of the Sierra Nevada.

Hence I can confidently state that the waters, which each of the schemes before mentioned will furnish, (except that from common and deep wells in the city), is of a suitable and excellent quality for domestic uses in San Francisco.

FOURTH.

The FOURTH branch of the enquiry is, "The character and extent of the works and the comparative expense of procuring the requisite quantity of water, of a suitable character for the present and future demands of the city, from each of the feasible sources."

The time allowed for the preparation of this report, will not permit me to enter into this part of the investigation with much detail, and I shall be compelled to express myself in more general terms than I would otherwise do.

Before taking up an examination of the several schemes for an efficient supply of water to San Francisco, it may be premised, that certain parts of the work must be substantially the same, from whatever source the water is supplied. The water from each of the sources must be received in capacious, elevated reservoirs, so located that the water distributed therefrom, while able to furnish the usual nearly equal daily supply, will also be able to answer the sudden demands for the extinguishment of a large conflagration. The distribution pipes in the streets, must be of suitable size to accomplish both of these objects.

The expense of constructing distributing reservoirs and of laying down the street pipes, must therefore be substantially the same for each one of the schemes.

It remains, then, to ascertain how the water from each source can be suitably introduced to the distributing reservoirs.

Commencing with the first of the schemes herein mentioned, "the supply from common and deep wells in the City:"

A properly arranged system, would require a series of wells to be sunk where a contour line of perhaps thirty feet above the level of tide, would strike the surface of the graded streets. These wells would be placed at such distances apart, as to intercept as much as possible of the subterranean flowing waters and not materially interfere with the supply to each other.

A second series of wells, dug on a contour line of greater elevation, would probably be necessary, and in particular places, the level of the ground, the condition of the sub-soil, and other circumstances might require some intermediate wells. When these wells are within a reasonable distance of each other, one pumping engine would serve for several. Receiving reservoirs of considerable capacity, would be required to meet the unequal demands for water, during the different hours of the day and night, and those of the days of the week. Several of the pumping engines could deliver their water into the same reservoir.

It is almost évident, even without a detailed estimate, that the cost of the pumping engines, wells, force mains and reservoirs, added to the sum, the interest of which would operate the engines, would be as great for its limited supply of six million of gallons a day, as the same quantity of water could be obtained by some of the other schemes.

If the waters of Lake Merced can be freed from vegetation they would probably be rendered of good quality. The quantity which it will furnish has been variously estimated at from five to ten millions of gallons a day. It is distant eight miles from the City Hall, with its surface elevated but little above the ocean. To make use of this water, it must be pumped over ground three or four hundred feet high, and then conveyed to reservoirs for distribution.

This source would not furnish water sufficient for even the present demand, and the scheme can only be considered as an adjunct to some one of much larger supply.

The nearest source of water, of a suitable quality and in sufficient quantity to supply the present and future demands of the City, is that from the elevated lands of the Peninsula immediately south of San Francisco. The Spring Valley Water Company has developed this source of supply, so far as to demonstrate, that a minimum of more than fifteen millions of gallons a day, can be obtained from their existing works, and thirty millions, as soon as they shall have completed another of their reservoirs. These works may also be extended so as to increase the daily supply from the whole Peninsula system, to fifty millions of gallons a day.

As the works have been in use many years, the description of them may be made very briefly.

There are three large storing reservoirs now in use, having an aggregate capacity for the storage of sixteen thousand seven hundred millions of gallons of the water, which is supplied from the flow-off from twenty-seven and a half square miles.

The water is conducted from these collecting reservoirs, through tunnels and wrought iron pipes, to seven distributing reservoirs, located on elevated hills throughout the City. These reservoirs will contain more than sixty millions of gallons, one half of which is in one reservoir, which is three hundred and seventy-seven feet above tide, and another of these reservoirs, containing fifteen millions, is two hundred and fifty-three feet above tide. These elevations are sufficient to give an effective head in the highest buildings in the highest parts of the city.

In 1875 there had been laid in the streets one hundred and sixty-seven miles of cast iron pipes, ranging from twenty-two inches in diameter downward, having a mean area equal to that of a pipe of 8.42 inches interior diameter. The length of the street pipes now laid is about one hundred and seventy-five miles.

The next nearest source of water, of suitable quality and sufficient quantity, is from the Calaveras District, which has already been described in part; a continuation of the description will be as follows:

The water from the Calaveras Reservoir, would be conveyed through the mountain which forms its western water-shed, by a tunnel two miles long, and then by a line of pipes twenty-one miles long, passing around the head of the Bay of San Francisco to a suitable elevation on the eastern slope of the Peninsula and along that slope by a conduit and pipes to reservoirs, which would have to be built on elevated places within the City, and distributed throughout the City as before mentioned.

The comparative expense of introducing water by the Calaveras scheme and the Spring Valley, is narrowed down to that of the high reservoir dam, long tunnel and twenty-one miles of pipes around the bay, in the former, and the cost of the reservoir dams now built and projected in the latter scheme.

The cost of the conduit along the peninsula slopes and that of the city reservoirs and distribution pipes, would be alike in both schemes.

Col. Mendell estimates the cost of so much of the above mentioned works of the Calaveras scheme, as enter into the comparison, at nearly seven millions of dollars, to bring a daily supply of thirty millions of gallons to the place of junction, beyond which the cost of the two schemes would be equal.

The cost of the already constructed reservoirs and appurtenances of the Spring Valley Works in San Mateo county, and of their enlargement so as to furnish thirty millions daily, is evidently less than this seven millions of dollars which the Calaveras scheme would cost.

Messrs. Schussler, Scowden and Mendell have investigated schemes for a water supply from the lakes and rivers on the slopes of the Sierra, from Clear Lake and from the San Joaquin, which may be generalized in description, as follows:

From Lake Tahoe on the Sierra Nevada. The water would be conveyed in a canal for fifteen miles, through a tunnel under the Sierra of nearly five miles in length, down the American River twelve miles, again by a canal of sixty miles, to a reservoir at Auburn, and then by an iron conduit pipe one hundred and one miles long, passing under the Sacramento River twice, to a reservoir at Carquinez. The conduit would commence with an elevation of 1,326 feet near Auburn, and after descending to the level of tide, would again rise to 626 feet elevation at Carquinez. From thence by a conduit pipe twenty-two miles long to Oakland, from which, by a tunnel of five miles under San Francisco Bay, it would be connected with the reservoirs and pipe distribution in the city. The entire length of the artificial work would be 208 miles.

The El Dorado project proposes to take the water of the South Fork of the American River, by a canal of forty-five miles in length to Borland, and then by an iron conduit pipe of eighty-two miles in length (passing under the San Joaquin) to Livermore Pass, and continued sixty-four miles to and under a comparatively narrow, shallow channel of the Bay, and down its western shore to the reservoirs in the City. Or if the line is carried around the head of the Bay, the distance will be increased eleven miles. The total length of this line is 191 to 202 miles.

The Mokelumne and Blue Lakes scheme proposes to take the water from the Mokelumne River, by a canal from thirty-eight to fifty-two miles long, and then by a conduit pipe on a line which intersects that above described for the El Dorado scheme, near the San Joaquin River, sixty-two miles to the Livermore Pass, and then following the same route to the City a further distance of sixty-four miles. The total length of the artificial work on this line is from 164 to 189 miles.

There have been some other schemes suggested for obtaining water for the City from other places along the western slopes of the Sierra Nevada, but the considerations which will presently be presented, will apply equally to all of these sources.

The scheme of a supply from *Clear Lake* consists of twenty-two and a half miles of canal and ninety-six and a half miles of iron conduit pipe, making a total length of artificial work of 119 miles, passing under the straits of Carquinez and the Bay of San Francisco.

The scheme of a supply from the *San Joaquin River* is mainly by an iron conduit pipe of fifty-seven miles to Oakland, through which the water will be forced by pumping engines, and thence by a tunnel under the Bay to the city reservoirs and distribution, or by a conduit pipe around the head of the Bay sixty-seven miles further, and a second pumping work. The total length of this line would be 124 miles.

Another plan is to pump the water from the San Joaquin River to a reservoir at Livermore Pass, and from thence convey it around the head of the Bay to the City reservoirs by an iron conduit pipe of eighty-four miles in length.

The general features of these several schemes have been presented in as brief and succinct a manner as possible, so as to enable the expresssion of opinions upon them in a group, as compared with the two other schemes for obtaining a water supply from the nearest sources, and thus narrow the discussion of the subject as much as possible.

It has been already stated that each of these several sources will furnish water of a suitable quality and in sufficient quantity to supply the present and future demand of the City.

The foregoing description of the plans, routes, etc., for the several last mentioned schemes shows that the hazards of construction, maintenance and cost are comparatively so great, that any further detailed examination of the cost is unnecessary at the present time for the purposes stated.

These brief descriptions show that all of these schemes require much longer lines of canals, pipes, etc; that they must be carried under one or more navigable water courses, or encounter the largely additional expense of a long detour around the head of the Bay; some of them involve the untried and questionable project of a long tunnel under the deep waters of the Bay, and others the constant charge for pumping the water. In fine, that each one must necessarily be very much more expensive in construction, and more costly and hazardous in maintenance than the Peninsula and Calavaras schemes.

In regard to all of the schemes except the combined one of the Spring Valley and Calaveras, it may be stated, that to complete them, so as to furnish and properly distribute as much water as can be obtained from the Peninsula system alone, would require an outlay fully double that of the latter, and to furnish a supply equal to the combined quantity which the Peninsula and Calaveras districts are capable of furnishing, by either one of the antagonistic schemes would cost many times as much.

If we omit from this comparison the hazards attending the construction and maintenance of the necessarily long lines of iron conduits, under excessive pressure, and partly submarine, the excessive cost of these conflicting plans alone, would preclude their further consideration, in comparison with the evidently simple and practically demonstrated plans of the Spring Valley and Calaveras system.

Respectfully yours,

WM. J. McALPINE.

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